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INSIDE

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"Science affects the way we think together."
Lewis Thomas

GROWING TREES WHERE TREES GROW BEST: SHORT-TERM RESEARCH SHEDS LIGHT ON LONG-TERM PRODUCTIVITY

Connie Harrington

The Fall River study on Weyerhaeuser Company land in Washington examines the importance of residual organic matter in sustaining soil productivity and the effects of competing vegetation and harvest-related soil compaction on tree growth.

"Given that the state of the soil determines what can be grown for how long, preserving the basis of wealth of future generations requires intergenerational land stewardship."
—David R. Montgomery, in *Dirt: The Erosion of Civilizations*.

Is growing trees as an "agricultural" crop sustainable? This question is important to forest managers in the Pacific Northwest who want a better understanding of the short- and long-term effects of intensive management on future forest productivity. Connie Harrington, a research forester at the Pacific Northwest Research Station in Olympia, Washington, and several collaborators from Weyerhaeuser Company and the University of Washington are nearly 10 years into The Fall River study—part of a long-term research program designed to answer longstanding questions about the impacts of intensive forest management on sustained productivity.

Three questions are at the heart of the study:

(1) How much does residual organic material—the branches, treetops, and other woody debris that are left after a harvest—alter the soil and affect future tree growth?

(2) Does competing vegetation significantly affect water and nutrient supplies and reduce tree seedling growth?

IN SUMMARY

In 1999, the Fall River Long-Term Site Productivity study began in coastal Washington to investigate how intensive management practices affect soil processes and forest productivity. By comparing conventional harvests to more intensive wood removal treatments, researchers are answering long-standing questions about how residual organic matter influences future growth. Also, by using herbicides to control competing vegetation, they are quantifying the influence other vegetation has on tree growth. Finally, they are measuring soil properties and tree growth on plots where the soil was not compacted during harvest and comparing results to those on plots that were either compacted by logging equipment or compacted and subsequently tilled to restore physical properties.

Several interesting findings have emerged after 8 years of measurements: Nitrogen pools in these soils are so high that conventional clearcutting and whole-tree plus coarse-woody-debris removal only reduced the total site nitrogen pool by 3 percent and 6 percent, respectively. That's a very small percentage reduction that is unlikely to affect long-term productivity. Vegetation control reduced competition for water during the dry growing season and doubled above-ground tree biomass at age 5 compared to the plots where vegetation was not controlled. Soil compaction did not reduce tree growth. These findings suggest that this site is very resilient to intensive forest management.

(3) What impact does ground-based harvesting equipment—such as feller-processors and forwarders, which are commonly used in intensive forestry—have on soil properties and tree growth?

"These questions are of particular interest to private landowners who intensively manage forests, because they provide the majority of American-grown wood products for American consumers," says Harrington.

The Fall River study is one of more than 40 affiliate research sites throughout the United States and Canada in the Long-Term Soil Productivity (LTSP) program initiated by the Forest Service in 1989. Fall River was the initial installation in the Pacific Northwest, and it shares some comparable treatments and many of the same objectives as the larger LTSP program.

The study site in Washington is owned by Weyerhaeuser Company and is typical of many coastal sites used by forest industry for intensive management in the region. The soil is particularly rich in nutrients and organic matter and can hold water like a sponge, meaning it's a great place to grow trees.

James Dollins

Questions about sustained, long-term productivity are of particular interest to private landowners who intensively manage forests.

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STRETCHING THE SYSTEM

The study includes four levels of organic matter removal, starting with a conventional clearcut harvest of second-growth Douglas-fir where the merchantable boles are removed but the branches and tops are left where they fall. From there, the intensity is ratcheted up, incrementally removing more and more of the woody material, culminating with the complete removal of all the aboveground tree biomass (organic matter) and even the old decaying logs, so that only the topsoil with remnant forest floor remains.

"We tried to stretch the system a bit so we can really see the impacts," says Thomas Terry, a retired senior scientist with Weyerhaeuser Company who oversaw the logistics of harvesting and treatment implementation, and collaborated on subsequent research.

Although clearcutting is the conventional harvest method throughout the region, situations exist in which most of the wood is removed. In the future, intensive wood removal could become an important source of cellulose for conversion to liquid fuels such as ethanol. But, for the purposes of the study, the intensive harvests were intended to accentuate the effects of organic matter removal on site productivity, not mimic any particular operational harvest. "Whole-tree harvesting plus removal of additional coarse woody material obviously removes more organic matter and thus more nutrients from the site than does conventional harvesting," says Harrington, "but the significance of leaving this material for the productivity of the subsequent stand is not clear."

Residual organic material may be an important source of nutrients—particularly nitrogen—if the soil is nutrient-poor to begin with. But that's not a problem at Fall River. According to Rob Harrison, University of Washington collaborator, the study sites have incredibly high levels of soil nitrogen, with almost 90 percent of the site's nitrogen pool contained in the mineral soil (0- to 32-inch depth). In fact, soil nitrogen was so high that the conventional harvest only removed 3 percent of the site's total nitrogen pool. Even more impressive: the most intense treatment removed only 6 percent of the nitrogen pool. "That's a very small percentage and one that's unlikely to have much of an effect on productivity," says Terry.

KEY FINDINGS

- On this fertile, moist site, removal of organic matter had very little effect on short-term tree growth. The conventional clearcut harvest removed 3 percent of the site's nitrogen pool, whereas the whole-tree harvest plus removal of legacy woody material removed 6 percent. Residual slash from clearcutting did increase the amount of nitrogen in soil 2 to 4 years after harvest; however, the total amount of nitrogen leached from the slash was small compared to the total mineral soil nitrogen pool.
- Annual herbicide treatments to control competing vegetation had a major influence on early tree growth. Vegetation control reduced water stress in tree seedlings during the dry summer. Douglas-fir aboveground biomass at age 5 was more than double in sites where competing vegetation was controlled compared to sites where vegetation was not controlled.
- Soils at the Fall River study sites had very low initial bulk density. Although soil compaction associated with ground-based harvesting did alter soil physical properties, it did not decrease seedling growth. Growth on compacted sites actually increased during a dry growing season owing to increases in the soil's moisture-holding capacity. Tilling compacted areas effectively returned soil properties to noncompacted levels, but was not needed to maintain tree growth.

David Peter

David Peter

A conventional harvest (left) removed 3 percent of the ntirogen pool while the most intense treatment (right) removed 6 percent.

The logging slash left on the conventional clearcut sites did produce an increase in soil-solution nitrogen 2 to 4 years after harvest. "However, the total amount of nitrogen leached from the slash was small compared to the total soil nitrogen pool," says Harrison. In addition, followup research by Harrison and his colleague Brian Strahm revealed specific chemical characteristics of the soil on this site that allow it to retain more soil nutrients, and thus make it more resilient to intensive management than predicted prior to this research.

According to Terry, "Organic matter removal did increase surface soil temperature and increased rate of drying of the surface soil in early years." As a result, there was a slightly lower growth rate on those plots during the relatively dry third growing season when tree shading effects were small."

"Longer term research will ultimately be needed to determine whether long-term site productivity has been impacted by biomass removal," says Terry.

DROUGHT IN A RAIN FOREST

Every year, for the first 5 years after harvest, one treatment in the Fall River study was treated with herbicides to control competing vegetation. At year 5, Terry and Kyle Peterson, a graduate student from the University of Washington, cut down and weighed a sample of the saplings on the treated and untreated sites to determine the effect of vegetation competition on short-term productivity. "On sites that had received vegetation control, it took two people to carry many of the trees, whereas one person could easily haul a tree from the untreated plots," recalls Terry. "The aboveground tree biomass was more than double in sites that had been treated."

"Trees in plots where competing vegetation was controlled had more branches and greater taper in the lower stem; thus, not only were trees on average smaller in plots without vegetation control, even trees of the same diameter weighed less. Plus there were differences in how the biomass was distributed between the branches, foliage, and stem," explains Harrison.

The effect of vegetation control on early seedling growth (age 5) was impressive, and it points toward the major limiting factor for early tree growth on this site: water.

"Although on some sites nontree vegetation may also be competing for nutrients, at Fall River we were able to determine that nutrients were not limiting growth by looking at foliar nutrient concentrations and following the effect of spot applications of fertilizer," says Harrington.

It may seem counterintuitive that in a temperate rain forest that receives almost 90 inches of rain annually, lack of water limits growth. "People come here in the winter when it rains every day, or they think about the annual precipitation for the area and they simply cannot believe that lack of water could limit tree growth," says Harrington. "But the rain is seasonal, and there's a predictable drought during most summers, right in the middle of the growing season."

The herbaceous plants that grow among the Douglas-fir seedlings are fierce competitors for water. The herbicides killed many of these competitors, thereby freeing up available water for the trees, a fact that was confirmed in a study looking at carbon isotopes in the wood.

Diana Livada

Douglas-fir seedlings on sites that received an annual application of herbicide to control competing vegetation were more than twice as heavy as seedlings without vegetation control.

Science Findings is online at: http://www.fs.fed.us/pnw/

The site includes **Science Update**—scientific knowledge for pressing decisions about controversial natural resource and environmental issues.

Harrington is quick to note that the aggressive regimen of herbicides did not eliminate all of the competing vegetation. "Many species had one or more 'escape mechanisms,' such as a perennial nature, prolific seeding, underground rhizomes, prostrate growth, or shade tolerance," she explains. "By the end of all the treatments, the majority of native species were still present on the site. Oxalis (wood sorrel) and violet persevered along the edges of logs and under branches. I was impressed with how resilient these seemingly delicate plants were in the face of multiple disturbances."

FIRM GROUND

Industrial forestry often requires heavy equipment, and anytime you drive a big machine into the woods, you run the risk of degrading or altering the physical structure of the soil. To hedge against this, some forestry organizations require operators to till the soil wherever soil compaction may have occurred.

The degree of compaction is measured by the increase in the soil's bulk density—its dry weight relative to its volume. Soil bulk density is low at Fall River—so low, in fact, that when outside researchers first see the data they often think there's an error. Low-density soils, such as these, are typical of those with ash content—a byproduct of volcanic activity—or high organic matter content, and are found on many sites in the Cascade and Coast Ranges.

Concern is often raised about soil disturbance and soil compaction. Recent studies show that soil compaction can be detrimental, have no effect, or even positively affect tree growth depending on the soil, climate, and degree of compaction. The Fall River study included treatments to assess the impact of compaction from harvesting equipment on soil processes and tree growth. Some plots were cable yarded—a harvest system that moves logs from the stump to the roadside using cables. Other plots were traversed with a shovel forwarder (logging equipment which travels across the plots picking up logs and moving them to the roadside). Equipment operators were asked to make double passes on some traffic lanes to simulate the level of compaction that might occur if two pieces of equipment were used (a mechanized feller to fall the trees and a forwarder to move the logs to a landing).

Thomas Terry

The harvest-related soil compaction at Fall River study site did not negatively affect seedling growth.

The extent of the compacted area on plots traversed with the harvesting equipment averaged 43 percent, which is substantial given that the Forest Service's standards in the Pacific Northwest region permit only 15 percent. What's more, the increase in bulk density on compacted areas was 26 percent, which is also above the regional standard of 20 percent.

On half of the compacted plots, all the traffic lanes used by the equipment were tilled in order to bring the soil back to its original density.

According to Harrington, after 5 years of measurements, soil compaction has not decreased tree growth. "In fact, growth on compacted sites actually increased during the driest growing season due to increases in soil moisture-holding capacity."

"Tillage of compacted areas was effective in returning soil properties to noncompacted levels, but was not needed to maintain productivity," says Terry. "Over the first 5 years, there was no difference in tree growth rates between the cable-yarded, compacted, or compacted and then tilled sites." These plots will be reassessed at age 10.

"It is important to note that in our study, movement of equipment used for harvesting did not displace or remove topsoil, cause soil puddling (churning under wet conditions), or disrupt surface hydrology—those are more serious types of soil disturbances that sometimes get lumped in with the effects of compaction," says Terry. "The tests we conducted were designed to assess the impacts of compaction only."

LAND MANAGEMENT IMPLICATIONS

- Retention of organic matter after harvest may increase soil nitrogen and surface moisture. On sites similar to Fall River, however, given the large initial nitrogen pools and the chemical characteristics of the soil, which allow it to retain nutrients, it seems unlikely that reductions in tree growth will occur as a result of the nitrogen removed through tree harvest.
- In areas of the Pacific Northwest with high levels of annual precipitation, it has been suggested that competing vegetation does not limit tree growth significantly. Because the region typically receives little precipitation during the summer, however, soil moisture deficits do develop. Tree growth may be reduced as trees and other vegetation compete for soil moisture and in some cases, nutrients.
- Soils in coastal Washington and Oregon are deep and have low bulk density and high organic matter content making them resilient and at low risk for detrimental effects from harvesting traffic compaction.

WORKING TOGETHER

For almost a decade, the Fall River study has been assessing dozens of aspects of short- and long-term forest productivity, only a fraction of which are discussed here.

"No single cooperator could have implemented the project alone," says Terry. "All collaborators benefited from developing and sharing—in a coordinated way—information to test multiple hypotheses about treatment effects and mechanisms of treatment response. In many studies, the results are interpreted with speculation on the effects of other unmeasured factors; this study has information available on many aspects, thus speculation about critical process factors was kept to a minimum, and a multidisciplinary team was available to interpret these data."

James Dollins

Hundreds of people including scientists, foresters, forestry students, forest managers, and educators have toured the Fall River study site.

According to Harrington, the success of the study can be attributed to the unfettered collaboration between Forest Service, private industry, and universities. "For one thing," she says, "this was a very expensive study to implement, and we were very fortunate that Weyerhaeuser Company bore the costs of study installation while other funding sources could be used to fully explore the mechanisms of treatment response."

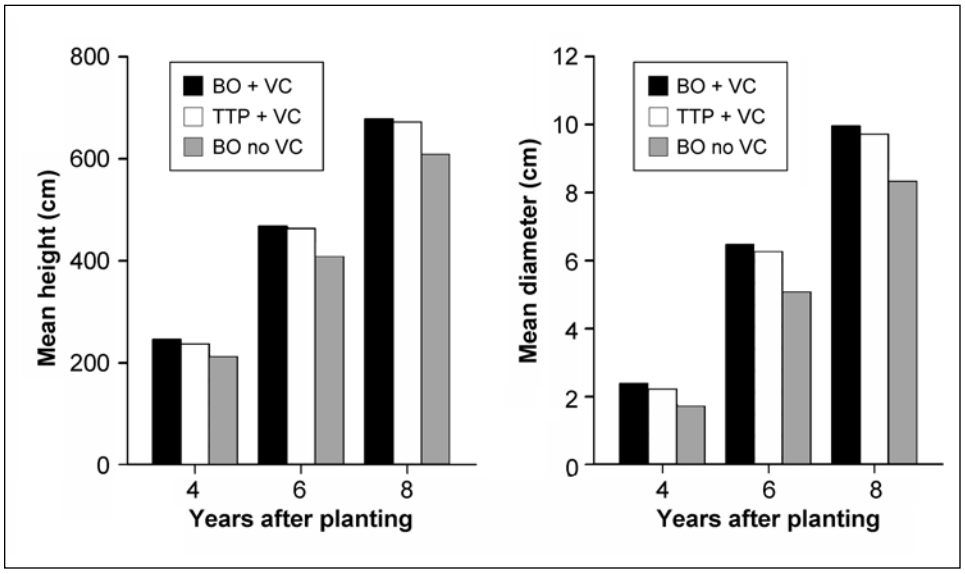
"Over the past 8 years, we've had a lot of field tours out there," she adds. "Hundreds of people including scientists, foresters, forestry students, forest managers, and educators have toured the sites. And we've published most of our findings and given many talks as well—we've really been able to get the word out."

Students especially have benefited from having exposure to industrial operations as well as the ideas and research practices used by other collaborators. To date, four graduate theses from the University of Washington have been written based on research done at Fall River, and many other students have been involved in the project.

Another beneficial outcome of the Fall River study is that two other forest products companies have installed similar site productivity trials. The two new trials cover different site conditions than Fall River, and together the three trials will provide a good foundation for assessing the effects of intensive management on long-term productivity.

"All terrestrial life ultimately depends on soil and water."

—Daniel J. Hillel, in *Out of the Earth: Civilizations and the Life of the Soil*



After harvest, young tree seedlings must compete with herbaceous plants for water during annual summer drought. At the Fall River study site, vegetation control (VC), through the annual application of herbicides, decreased competition and increased the growth of tree seedlings in both the "bole only" (BO) and the total tree plus removal of legacy wood (TTP) treaments.

FOR FURTHER READING

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Other publications from Fall River are listed online, and electronic copies of all the publications from the study are available at: http://www.fs.fed.us/pnw/olympia/silv/publications/fallriverpubs.shtml

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